

Urban biodiversity: a double-edged sword

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Abstract

Urban biodiversity is a complex but promising phenomenon that allows humans and wildlife to coexist in cities. Green urban spaces serve as vital habitats, connecting natural areas and fostering biodiversity. Despite challenges such as habitat loss, it has been observed that bird populations are adapting and few plant species taking refugees in road side and railway track. Designing environmentally friendly green spaces is critical for balancing urban development with the natural environment. Infrastructure projects have an indirect impact on green spaces, necessitating sustainability-focused strategies. Soil improvement and sustainable water management, according to research, promote native plant growth. Urban biodiversity management necessitates a harmonious blend of conservation and economic development, fostering investment in environmentally friendly green spaces that mitigate the negative effects of urbanization while preserving biodiversity.

Keywords: Urban biodiversity, Green urban spaces, Habitat loss, Environmentally friendly green spaces, Sustainable management

1. Introduction

Urbanization, an unstoppable force in our modern world, is rapidly transforming the Earth's landscapes, converting once-pristine natural habitats into sprawling cities and suburbs. This relentless expansion poses significant threats to the delicate tapestry of life that we call biodiversity. Yet, within the confines of concrete and steel, urban environments also present unique opportunities for the coexistence of humans and wildlife. In this essay, we embark on a journey through the double-edged nature of urban biodiversity, where we venture into the heart of

bustling metropolises to explore both the potential benefits and inherent challenges it brings.

Urban areas, marked by their bustling streets, towering skyscrapers, and constant human activity, may not appear as sanctuaries for biodiversity at first glance. However, hidden beneath the concrete jungle lies an intricate web of life, awaiting our understanding and appreciation. Indeed, cities have the potential to serve as vital refuges for certain species, contributing to the conservation of biodiversity in unexpected ways. The presence of green spaces, such as parks, gardens, and street trees, provides essential habitats and resources for a surprising variety of plant and animal species [1]. These urban green oases act as essential stepping stones, connecting fragmented natural habitats and facilitating the flow of genes among populations [2]. Furthermore, urban areas, with their proximity to human activities, support a diverse range of species that display a remarkable tolerance for our presence, often resulting in the remarkable phenomenon of high species richness within city limits [3].

The presence of thriving urban bird populations is a shining example of the positive aspect of urban biodiversity. Birds have proven to be remarkably adaptable to urban life's challenges, capitalizing on the resources provided by green spaces and anthropogenic food sources [4]. Surprisingly, urban habitat provides them with protection from predators that exist in natural ecosystems, contributing to higher breeding success rates for some bird species [5]. Furthermore, studies have shown that urban areas can provide vital stopover sites for migratory birds on their long journeys [6]. Cities are thus more than just concrete jungles; they are home to a diverse avian community, which contributes to the overall conservation and genetic diversity of bird species.

Nevertheless, amidst the skyscrapers and bustling streets, urbanization brings with it a plethora of challenges for biodiversity. The relentless march of development results in the destruction and fragmentation of natural habitats, leading to the loss of native species and a decline in the vital ecosystem services they provide [7]. Even more

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concerning is the introduction of exotic species, which often occurs as an unintended consequence of urbanization. These newcomers can outcompete and displace native species, pushing them to the brink of extinction and ultimately causing a decline in overall biodiversity [8]. Additionally, the pollutants that accompany urban life, such as air and water pollution, further hinder the movement and survival of wildlife in urban areas [9]. Artificial barriers like roads and buildings create physical obstacles, isolating populations and disrupting essential migratory routes.

The alarming decline of native bee populations, critical pollinators that support ecosystem functioning and global food security, is a stark example of the negative impact of urban biodiversity. Urbanization has a direct impact on

their foraging opportunities by reducing the diversity of floral resources and exposing them to harmful pesticides [10]. The extinction of native bees not only impedes plant reproduction but also disrupts the intricate ecological networks of which they are a part [11].

Urban biodiversity emerges as a complex and multifaceted phenomenon in the intricate movement between human progress and the natural world. As we traverse the dynamic landscape of urban environments, it becomes increasingly apparent that the future of biodiversity, both within and beyond city limits, is intrinsically linked to our ability to understand, appreciate, and mitigate the dual nature of urbanization's impact on the ecosystems we share with countless species.

Table 1: Two school of thoughts: Positive and negative aspects.

Two school of thoughts	Positive Aspects	Challenging Aspects
High richness of plants and animals	Cities can host a high richness of plants and animals [12].	Urbanization destroys and fragments natural ecosystems [13].
Efficient use of land	Compact living allows for the efficient use of land, enabling cities to preserve valuable green spaces and protect biodiversity [14].	Urbanization poses challenges to ecological sustainability [15].
Novel biotic communities and habitats	Urbanization creates novel biotic communities and habitats [13].	The spatial arrangements of habitats, species pools, and a species' adaptability and natural history affect the actual occurrence of a species [13].
Vibrant and diverse urban culture	Cities can support a vibrant and diverse urban culture, fostering creativity, innovation, and social interaction [16].	The role of non-native species in urban landscapes is complex [13].
Social thinking dimension	Urbanization can become a positive force, helping cities thrive despite an uncertain future [17].	Urbanization can cause harm to the environment. [15]
Natural aspect or further urbanization	Urbanization can create chances to support the natural aspects of city green spaces [12].	Protected areas can have both positive and negative effects because they can encourage urban development in their vicinity [18].

2. Positive Aspect:

2.1. Ecological Benefits:

- Increased species diversity: Urban areas with high biodiversity can support a variety of plant and animal species, leading to healthier and more resilient ecosystems.

- Improved ecosystem services: Biodiversity in urban settings can enhance pollination, nutrient cycling, soil fertility, and water regulation, thus improving overall environmental quality.

Gaston et al., 2010 [19] discuss how having more green and diverse natural areas in cities can improve general well-being, help the economy, and protect the environment. Blanco and their team, 2021 [20], discuss a new approach to city planning. They want to make cities work more like natural ecosystems and help the environment. They think this can make people and nature healthier. But, we still need to study more to make sure these ideas work better. We need to understand how ecosystems work and how they help us. Newman et al., 2011 [21] mentioned that "Biophilic Urbanism" means designing cities with nature in mind, like having plants and green spaces in and around buildings. Many important government goals, such as combating climate change, making cities cooler, using less energy, and making people healthier and happier, can benefit from this. Aznarez et al. 2023 [22] found that socioeconomic and historical factors, particularly luxury (wealth-related) and legacy (historical management), influence urban nature distribution and characteristics in Vitoria-Gasteiz, Basque Country. Higher education levels were associated with higher urban biodiversity (luxury effect), whereas older areas had more plant cover and ecosystem services (legacy effect), but this was associated with lower biodiversity due to recent biodiversity-promoting efforts. The luxury effect was amplified by habitat quality, and the legacy effect was amplified by population density, highlighting the interplay of these factors in shaping urban ecosystems. Marselle and colleagues 2021 [23] argue that caring for nature in cities is a smart way to improve public health. They claim that biodiversity, or the presence of a diverse range of plants and animals, is essential for maintaining the health of our environment, which in turn helps to maintain the health of people. This way of thinking places urban biodiversity at the heart of both nature conservation and making cities healthier for residents. It shows how nature in cities can be good for both the environment and the well-being of the people who call those cities home.

According to Soanes et al., 2023 [24], urban biodiversity conservation is critical to addressing the global biodiversity crisis and fostering a connection between people and nature. It highlights that urban biodiversity is often overlooked in urban planning and management.

Protected areas, green infrastructure, and citizen science projects are examples of current conservation practices. However, challenges to urban biodiversity conservation include a lack of funding, a lack of political support, and a lack of awareness of its importance. Collaboration between government, non-governmental organizations, and communities, as well as the use of innovative technologies and citizen science initiatives, are all enabling factors. This review emphasizes the importance of a multidisciplinary approach and calls for greater awareness and understanding of the importance of urban biodiversity among decision-makers and the general public.

According to Faeth et al., 2012 [25], as cities grow, the environment becomes fragmented and transformed, affecting the types of plants and animals that can live in these areas. Mao et al., 2013 [26] emphasizes that urbanization results in a shift in the distribution of biodiversity, leading to a decrease in native flora and fauna and an increase in non-native species, resulting in greater uniformity. Faeth et al., 2012 [25] also mentioned that while urban areas may have a greater variety of plants due to the introduction of non-native species, there is typically a reduction in the diversity of animals such as herbivore and pollinators, chances of crop failure. Shwartz et al., 2013 [27] underscores the significance of local-scale management in maintaining biodiversity in small green spaces within cities. In summary, urban biodiversity tends to exhibit reduced native biodiversity and increased non-native biodiversity, with the overall impact on species diversity varying depending on the specific group of plants and animals and the particular urban context. Now it's a good time to look at the natural places in cities because we can learn about things like how communities are affected, how areas change, and how new species come in and live with the ones already there.

Milliken, 2018 [28] reported on the economic benefits of urban ecosystem services, emphasizing the importance of presenting these benefits in monetary terms for the understanding of policy and decision makers. Various tools, such as the green infrastructure valuation toolkit and i-Tree software, were highlighted as valuable for quantifying the economic value of ecosystem services, including pollution removal, carbon storage, storm water reduction, and more. These economic valuations offer a comprehensive framework to assess the returns on investment in urban landscape schemes. Furthermore, it was noted that urban morphology plays a pivotal role in the provision of multiple ecosystem services, and the development of dense, compact cities can impact service provision and urban biodiversity. Engineered green infrastructure, like green roofs

and vertical greening systems, provides opportunities to enhance connectivity in densely populated areas, creating ecological networks that facilitate the flow of benefits dependent on these structures. Urban planning should harness these tools to foster a synergy between ecosystem services and human well-being.

Ecosystem services are vital benefits provided by nature, spanning provisioning, regulating, cultural, and supporting services. Urban areas, including green infrastructure, are hubs for generating these services. Provisioning encompasses urban farming and resource recycling. Regulating services mitigate pollution and offer carbon storage, noise reduction, and temperature control. Cultural services enhance mental health and community well-being, making their recognition essential in urban planning. Supporting services, rooted in habitat provision and biodiversity, are fundamental to all ecosystem services. Expressing these services in economic terms aids decision-making. Urban planning's focus on connectivity and engineered green infrastructure is key to maximizing these urban benefits.

2.2 Aesthetics and Well-being:

Psychological benefits: Urban areas with diverse flora and fauna can provide a sense of connection to nature, promoting mental well-being, stress reduction, and improved quality of life.

Visual appeal: Green spaces and wildlife habitats within cities enhance the aesthetic quality of urban environments, making them more attractive places to live and visit.

Urbanization has become an increasingly prominent facet of modern society, transforming the landscape and altering the environment in profound ways [29]. As our cities expand and human populations surge, urbanization carries with it a set of environmental challenges that are both intricate and far-reaching. One of the key components in understanding and addressing these challenges lies in unraveling the intricate relationship between urban development and the natural world. This is where urban-rural gradient studies enter the scene, offering a valuable lens through which to examine the impact of urbanization on biodiversity [30]. There is immediate need to study the intriguing patterns that emerge as one traverses the spectrum from densely populated urban epicenters to the less altered, more pristine rural landscapes. This scrutinizes how plant and animal populations change along this continuum, revealing a host of transformations that provide crucial insights into

the intersection of human civilization and the natural world. As transformations are the physical changes that escalate as approaching the urban core, with surges in population density, is mirrored by a surge in road density, more polluted air and soil, notable shifts in temperature and precipitation patterns, and the proliferation of impervious surfaces, such as pavement and buildings. Concurrently, urban areas are characterized by an increased import of resources intended for human use, further exacerbating their impact on the environment. The process of construction in urban areas, so intrinsic to urbanization, often brings with it the grim tale of habitat destruction. Trees fall, vegetation vanishes, and topsoil is displaced. This upheaval translates into a significant loss of native biodiversity. Even after construction is completed, the urban environment continues to be unforgiving, as paved surfaces consume vast tracts of potential habitat, leaving little room for native species. What remains is often graced with nonnative vegetation, further undermining the preservation of local biodiversity. The urban environment, with its unique set of challenges and opportunities, also plays host to an increasing proportion of nonnative species as one ventures deeper into the urban core. The swelling human population densities in this region facilitate the importation of these nonnative species, giving rise to a vibrant but often disruptive array of inhabitants.

The journey to preserve and restore biodiversity in this urban landscape is marked by a twofold approach - preservation and restoration. Urbanization casts a complex shadow upon the inhabitants of the natural world, and the degree of adaptation to urban life varies across species. This differentiation gives rise to three distinct categories: "urban avoiders," "urban adapters," and "urban exploiters," each demonstrating varying degrees of dependence on human resources, from minimal reliance to complete dependency [31].

3. Negative Aspect:

3.1 Habitat Destruction:

The construction of buildings, roads, and other urban infrastructure can result in the direct destruction of natural habitats, such as wetlands, forests, and grasslands. In this context Land conservation can buffer local climate changes and enhance genetic diversity, but human intrusions must be managed. Potential solutions include treating ecosystem services as an urban utility, protecting biodiversity hotspots under urbanization pressure, and international coordination for urban sustainability. Urban areas

significantly impact ecosystem services, especially freshwater provision, which is crucial for residential, industrial, and commercial purposes. However, urban areas also affect the quality and quantity of available freshwater resources, posing challenges for many cities, particularly those in semiarid and arid climates [32]. Urbanization also impacts regulatory hydrological services, leading to increased surface water runoff and the vulnerability of downstream communities to flooding due to impermeable surface area expansion. Urban areas depend on upstream natural habitats for regulating water flows, creating a complex interdependence [33]. To minimize habitat and biodiversity loss and protect ecosystem services, cities should integrate ecological knowledge into urban planning practices [34]. Effective urbanization strategies require the coordination of ecological knowledge and practices between researchers and stakeholders, including citizens, community organizations, planners, and government representatives [35]. Research on urbanization's impact on biodiversity and ecosystem services raises questions about urban-rural interactions, feedback mechanisms, and cultural values [36]. Interdisciplinary approaches are vital to understanding trade-offs in ecosystem services for various urban socio-economic groups. The development of a theoretical framework, including cultural services, is crucial for inclusive urban planning [37].

3.2. Climate Change:

Urban areas often have a higher concentration of greenhouse gas emissions, contributing to climate change, which can affect the distribution and behavior of many species. In context of climate change microbes, plants, and animals, serve as crucial indicators of climate change impacts on ecosystems, aiding in the mobilization of public support and political action [38]. The first and foremost observation it has been observed the changes in plant trait like canopy height, leaf area, and specific leaf area [39]. These changes challenge assumptions of nutrient limitation in the face of climate warming (due to Elevated atmospheric CO₂) or physiological mal functioning [40]. Another study shows that climate change and its consequences are likely to affect micronutrient malnutrition by limiting the availability of micronutrient-rich plant and animal foods rather than their micronutrient content (41). Here the need of the hour to identify the key stone species - Keystone species are essential not only for conserving biodiversity but also for safeguarding ecosystem services and promoting resilience against environmental challenges [42]. Recognizing their multidimensionality should guide conservation efforts, emphasizing their role in maintaining ecological communities and

processes [43]. According to Timóteo et al., 2021 [44] global meta-analysis emphasized that keystone species' importance extends across multiple niche dimensions, impacting various ecosystem functions. Removing or reducing keystone species can trigger ecological disruptions, affecting the stability and functionality of ecosystems. Recognizing the multifaceted role of keystone species is crucial for biodiversity conservation and ecosystem resilience. Conservation management should consider the complexity of interactions in natural systems, as the removal of a single keystone species can have far-reaching consequences. Conservation of keystone species can indirectly safeguard entire ecosystems and the species dependent on them, contributing to both biodiversity conservation and ecosystem resilience [43]. This keystone species thrive only when they capable to live on multiple niches-and in case of animals - Maternal effects played a significant role in shaping these differences, challenging the assumption of a direct link between habitat preferences and reproductive success.

While these negative aspects of urban biodiversity are significant, it's also essential to acknowledge the positive aspects. Urban areas can provide refuge for some species, and there are opportunities for conservation efforts, urban greening, and sustainable urban planning that can enhance biodiversity and support coexistence between humans and nature.

Urbanization, through its habitat destruction and creation, can favor both native and non-native species adapted to urban environments, potentially leading to a loss of biodiversity in natural ecosystems and the introduction of non-native species [13]. Human presence in urban areas triggers avoidance behavior in wildlife, underscoring the role of human disturbance in wildlife population declines [45]. However, the presence of wild plants and animals in neighborhoods may not align with resident preferences [46]. Despite these negative impacts, urban areas can host diverse plant and animal species, supporting various ecosystem services [47], and contribute to achieving the Convention on Biological Diversity's goal of biodiversity preservation [13]. Through strategic planning and a commitment to sustainable practices, cities can navigate the challenges of urbanization, working towards a more environmentally friendly, inclusive, and prosperous future.

Addressing these challenges typically entails implementing strategies like urban planning, conservation efforts, and involving communities to foster eco-friendly, diverse urban spaces, while the "double-edged sword" concept underscores the

importance of balancing urban development with biodiversity conservation in cities.

3.3 Pollution:

Urban areas can be significant sources of pollution, including air pollution, water pollution, and noise pollution. These pollutants can harm wildlife and disrupt ecosystems, leading to declining biodiversity. Pollution can also lead to a loss of biodiversity in natural ecosystems and the introduction of non-native species. Human-caused disturbance, resource changes, and loss of environmental heterogeneity in urban ecosystems are known to affect soil biodiversity, and cause the differences observed between urban and natural soil systems [48].

3.4. Invasive Species:

- Introduction of non-native species: Increased urban biodiversity may include invasive species that can disrupt native ecosystems, outcompeting local species and causing ecosystem imbalances. Non-native species can prey upon or compete with native species, leading to declines in their populations and potentially causing local extinctions.

The example of the negative impact of non-native species is the kudzu vine (*Pueraria montana*), which is an invasive plant species in the southeastern United States that can grow rapidly and smother native vegetation [49]. Another example is the European starling bird (*Sturnus vulgaris*), which is a non-native bird species in North America that can outcompete native bird species for nesting sites and food (www.nwf.org) [50]. *Polygonum cuspidatum* is an invasive plant species in the UK that can cause damage to buildings and infrastructure [51]. *Heracleum mantegazzianum*- giant hogweed this is an invasive plant species in North America that can cause severe skin irritation and blindness [49]. *Bromus tectorum*, known as downy brome, drooping brome or cheatgrass, is a winter annual grass native to Europe, southwestern Asia, and northern Africa; it greens up and sets seed earlier than most native species, giving it an advantage over slower-growing native species (www.fs.usda.gov) [52]. It can prevent native plant germination by depleting soil moisture in the spring. *Lantana camara*, water hyacinth, and *Parthenium* are harmful in India for different reasons. They harm the environment and local plants, sometimes causing allergies in people and animals.

Leucaena leucocephala, another invasive plant, is a problem in various places due to its fast growth

and how it harms local plant diversity. It may also affect other plants by stopping them from growing properly.

A study by Mello & Oliveira in 2016 [53] looked at how *Leucaena* affects native plants on a Brazilian island. In the lab, it didn't seem to stop the native *Erythrina velutina* from growing. But in the wild, *Erythrina* had a harder time near *Leucaena* trees. The local *Capparis flexuosa* plant sometimes helped *Erythrina* and sometimes didn't. When both *Capparis* and *Leucaena* were around, they hurt *Erythrina* more than *Leucaena* alone; showing that different plants can affect each other in complicated ways when one is invasive.

3.5 Human-Wildlife Conflicts:

- Property damage and health risks: A higher diversity of wildlife in urban areas can result in conflicts such as crop damage, property destruction, and increased risks of zoonotic diseases.

- Safety concerns: Urban ecosystems with high biodiversity may attract potentially dangerous species, such as venomous snakes or aggressive animals, posing risks to human safety.

In a study Narango et al., 2018 [54] showed the negative impact of nonnative plants on insectivorous birds and the ecosystems they inhabit. These nonnative plants disrupt the natural balance by reducing the availability of insects, which are a vital food source for insectivorous birds. This disruption has far-reaching consequences for the entire ecosystem.

For example, the study conducted on Carolina chickadees in residential areas shows that as nonnative plants increase, the bird population's ability to find enough insects and reproduce declines. It's also noteworthy that maintaining nonnative plants at less than 30% of the plant biomass is necessary to sustain bird populations. This research highlights the importance of prioritizing native plant species in efforts to restore human-dominated areas, as these plants are crucial for supporting the local food web and maintaining a healthy ecosystem.

Johnson and their team [55] looked at how invasive plants can thrive or struggle in new environments when they interact with other species. They focused on three invasive plants, Japanese knotweed and its close relatives, which are known troublemakers in North America and Europe. These invasive plants have a trick up their sleeves – special nectar-producing parts that attract friendly insects in their home in Japan. But

when they were taken to North America as decorative plants, they also brought along some foes, like the Japanese beetle, which became a common pest. The scientists wanted to figure out how these insect interactions affected the success of these invasive plants in North American cities. They checked out things like ants visiting the plants, how many Japanese beetles were around, their eating habits, and other stuff like who came to the flowers and how seeds were made.

What they found was quite interesting. Most of the plant damage in North America was done by Japanese beetles, but it was not as bad as in Japan. This means these invasive plants had fewer enemies in their new home. And here's a cool tidbit: ants liked the new leaves of these plants more than the older ones, and Japanese beetles usually munched on the older leaves. Also, native ants in North America visited the nectar parts of these invasive plants, and some even protected them from Japanese beetles. To top it off, both native and non-native insects visited the plants' flowers, helping make seeds. So, the study suggests that native and non-native species, through their actions like pollinating and protecting, can help these invasive plants spread. This is a big deal and reminds us of the importance of keeping native plant species in cities to help local insects and keep our environments healthy.

According to a study by Sun et al., 2023 [56], suggests that the absence of plant biodiversity in urban areas can lead to an increase in termite aggression, ultimately resulting in substantial damage to wooden property. The study found that human-caused disturbance, resource changes, and loss of environmental heterogeneity in urban ecosystems can affect soil biodiversity and cause differences observed between urban and natural soil systems. The loss of top predators and altered habitat characteristics in urban ecosystems can result in functionally destabilized food-webs, including those in soil, and result in changes to trophic cascades that benefit certain soil biota groups, including termites. The study suggests that promoting plant biodiversity in urban areas can help reduce termite aggression and damage to wooden property.

The dynamics of urban ecosystems, specifically in relation to insects and disease vectors, reveal complex interactions influenced by a variety of factors. The loss of top predators, such as birds of prey, and alterations in habitat characteristics within urban environments can lead to destabilized food webs, affecting trophic cascades. This, in turn, can benefit certain soil biota groups, including termites, ants, and snails. These organisms pose risks as they can potentially damage buildings, hinder plant performance, and transmit human pathogens. Such perturbations in

urban settings highlight the delicate balance of ecosystems in the face of urbanization.

In the context of mosquito vectors and urbanization, studies have indicated a concerning trend. Urbanization processes contribute to the proliferation of mosquito vectors of anthroponotic vector-borne diseases, exemplified by *Aedes aegypti* and *Culex quinquefasciatus* in Miami-Dade County, Florida. A natural enemy is another mosquito *Toxorhynchites splendens* entirely non-blood feeding feed on the larvae of pest species and other aquatic insects and consume larvae of other mosquito species occurring in tree crevices [57].

Furthermore, urbanization is linked to changes in mosquito biodiversity, and this has implications for mosquito-borne viruses. Decreased mosquito biodiversity is associated with higher levels of urbanization, fostering conditions where arboviruses thrive, often tied to the prevalence of a single predominant mosquito species like *Culex perexiguus*. This connection underscores the need to understand the intricate relationship between urban growth and the emergence of arboviruses.

3.6. Urbanization Pressures:

While urban biodiversity provides numerous ecological and aesthetic benefits, it is crucial to address the negative aspects and implement measures for sustainable urban planning and management. Balancing the advantages with the potential pitfalls can lead to a healthier coexistence between urban environments and their inhabitants.

Urbanization, characterized by the rapid expansion of cities and human settlements, is one of the most significant drivers of habitat loss and fragmentation, as well as the intensification of the urban heat island effect. This essay explores the impact of urbanization pressure on the loss and fragmentation of habitats, as well as the formation of urban heat islands [18].

3.7. Habitat Loss and Fragmentation

The process of urbanization involves the conversion of natural landscapes and ecosystems into urban areas, resulting in the loss of critical habitats for various plant and animal species. Encroachment upon natural habitats leads to habitat destruction, as entire ecosystems are cleared for the construction of buildings, infrastructure, and roads [58]. This loss of natural habitats directly impacts biodiversity and disrupts ecological processes.

Moreover, urbanization causes habitat fragmentation, where remaining natural areas become isolated patches surrounded by an urban matrix. Fragmentation of habitats can have severe

consequences for wildlife by reducing connectivity and disrupting migration patterns, leading to decreased genetic diversity, increased isolation, and higher extinction rates [59]. The decline of species richness and the disruption of ecological interactions are common outcomes due to habitat loss and fragmentation.

3.8. The Urban Heat Island Effect

The urban heat island effect refers to the phenomenon where cities experience significantly higher temperatures compared to surrounding rural areas. Urbanization intensifies the heat island effect by altering land use patterns, modifying vegetation cover, and increasing the amount of impervious surfaces, such as concrete and asphalt [60]. These changes result in reduced evapotranspiration, increased heat absorption, and limited natural cooling mechanisms.

The rise in temperatures in urban areas can have detrimental consequences on human health, energy consumption, and overall ecological processes. Excessive heat exposure can lead to heat exhaustion, heatstroke, and even increased mortality rates, particularly among vulnerable populations [61]. The urban heat island effect also exacerbates the demand for energy, as air conditioning and cooling systems are required to maintain comfortable indoor temperatures. Additionally, elevated temperatures in urban areas can disrupt natural processes, such as altering plant growth patterns, affecting wildlife behavior, and reducing water availability.

The pressure of urbanization leads to habitat loss, fragmentation, and the exacerbation of the urban heat island effect. These impacts have severe consequences for biodiversity, ecological functioning, and human well-being. It is crucial to recognize the importance of preserving and restoring natural habitats within urban areas and implementing sustainable urban planning strategies that prioritize green spaces, promote connectivity, and mitigate the urban heat island effect. By doing so, we can create more livable cities that coexist harmoniously with nature, protect biodiversity, and enhance the overall quality of life for urban residents.

4. Strategies for Sustainable Urban Planning

4.1 Designing Ecologically Friendly Green Spaces

The significance of ecologically friendly green spaces in urban development cannot be overstated. Urban planning in places like Surabaya should

prioritize ecological balance as a fundamental goal. This means that the design and development of urban areas must aim to maintain a harmonious relationship between human progress and the natural environment. The challenges faced in highly populated metropolitan regions, such as Rungkut Madya Street, underscore the need for this balance. These areas often contribute significantly to pollution and environmental issues, including dust, heat, and noise pollution, adversely affecting the quality of life for residents.

Infrastructure projects of two roads in Rungkut Madya Street, Java, Indonesia, could encourage the conversion of green areas into buildings due to the high value of land along these roads, leading to a decrease in overall greenery. To tackle these issues and enhance the urban environment, a qualitative research technique was used to observe and characterize existing green spaces with the primary aim of improving streetscapes and green space design [62].

Urban green spaces, including parks, gardens, and urban forests offer numerous environmental, social, and health benefits, such as improved air quality, reduced urban heat island effects, and recreational opportunities. However, as cities expand and urbanization progresses, the design and management of green spaces must evolve to address environmental concerns. This study explores strategies for developing environmentally friendly green spaces, emphasizing the incorporation of sustainable approaches and the preservation of biodiversity.

The significance of ecologically friendly green spaces is twofold. Firstly, well-designed green spaces can mitigate the urban heat island effect by providing shade and cooling through evapotranspiration, thereby reducing energy consumption for cooling buildings. Secondly, these spaces contribute to biodiversity protection, which is crucial for the sustainability of local ecosystems. Maintaining a diverse range of plant and animal species in urban green spaces is essential, as highlighted by Dallimer et al., 2019 [63]. Ecologically friendly green areas can attract and support animal populations by cultivating a varied range of natural flora and providing habitat niches, thereby contributing to urban biodiversity conservation. In Latvian urban green space planning, two primary factors take precedence: aesthetics and ecology [64].

In Eugene, Oregon, the Friendly Area Neighborhood employed Delphi analysis to explore various planting plans aimed at enhancing urban ecosystem services. Stakeholder priorities, identified through surveys and Delphi analyses,

include air quality, storm water quality, native plantings, and pollinator habitats. The willingness of residents to provide financial support influenced the development of diverse planting options. Reshaping urban green spaces, as emphasized by Devy et al., 2009 [65], necessitates the involvement of multiple stakeholders, including local municipality architects and, significantly, community residents. Furthermore, it must adhere to the principle of adaptive co-management.

Ecologically friendly green space design principles emphasize the selection of native plants. In Edmonton, Alberta, Canada, research by Rojas et al., 2021 [66] demonstrated that soil amendment with compost and proper site preparation positively influences the naturalization of native trees and shrubs in urban environments, leading to improvements in soil texture, acidity, electrical conductivity, and total carbon.

A study conducted by Calviño et al., 2023 [67] emphasizes the critical role of green roofs in urban green infrastructure. Green roofs offer environmental benefits, including providing habitats for arthropods. With the rising adoption of green roof technology in South American cities, the selection of local or alien plant species becomes crucial for their success. The study employs an integrative multicriteria decision framework to assess the potential of native and alien plant species on green roofs. The research, conducted in Córdoba, Argentina, compares the performance of six native and six foreign species on 30 experimental green roofs. The findings reveal that native plants, even without management, outperform alien species, displaying higher occurrence and somewhat greater cover. Notably, native annuals demonstrate the ability to reseed the following season, underscoring the importance of longevity as a relevant plant feature for future research.

Green spaces can also be instrumental in sustainable water management. Rain gardens and permeable pavements, as exemplified in the study by Song, 2022 [68], are sustainable water management strategies that help minimize runoff and improve water quality while educating people about the importance of water conservation. Such elements can contribute to the overall sustainability of green spaces, creating environmentally friendly urban environments that enhance the quality of life for residents.

In conclusion, the design and development of ecologically friendly green spaces are essential components of urban planning. These spaces not only mitigate the negative impacts of urbanization, such as the urban heat island effect and habitat loss, but also contribute to the preservation of biodiversity and the overall well-being of urban

residents. Incorporating native plants, involving the community, and adopting sustainable water management practices are crucial steps in achieving the ecological balance necessary for harmonious urban development.

5. Conclusion

Urban biodiversity is indeed a double-edged sword, as it presents both opportunities and challenges. While urban areas can support a diverse range of species and contribute to conservation efforts, the process of urbanization also leads to habitat loss, fragmentation, and the introduction of invasive species, which negatively impact native biodiversity. However, it is crucial to recognize that urban biodiversity can be managed in a way that is sustainable for both the ecology and the economy.

Finding a balance between ecological conservation and economic development is imperative for creating truly sustainable cities. Sustainable urban planning can integrate green spaces, such as parks, gardens, and tree-lined streets, which not only provide habitats for wildlife but also enhance the quality of life for urban residents. Implementing measures to protect and restore natural habitats within cities, while also promoting connectivity and biodiversity corridors, can mitigate the negative effects of urbanization on biodiversity.

Furthermore, considering the economic benefits derived from urban biodiversity can encourage policymakers and urban planners to prioritize its preservation. Urban ecosystems offer numerous ecosystem services, including improved air and water quality, temperature regulation, and pollination, which directly contribute to human well-being and economic prosperity. Recognizing the economic value of urban biodiversity can help encourage investments in conservation and sustainable urban development.

The design and development of ecologically friendly green spaces are essential components of urban planning. These spaces not only mitigate the negative impacts of urbanization, such as the urban heat island effect and habitat loss, but also contribute to the preservation of biodiversity and the overall well-being of urban residents. Incorporating native plants, involving the community, and adopting sustainable water management practices are crucial steps in achieving the ecological balance necessary for harmonious urban development

In conclusion, urban biodiversity presents both challenges and opportunities. By acknowledging the double-edged nature of urban biodiversity and promoting sustainable practices that prioritize both ecological conservation and economic development, we can create cities where humans

and wildlife can coexist harmoniously. Striking this balance will ensure that urban areas not only thrive economically but also maintain healthy and vibrant ecosystems, ultimately leading to a more sustainable future for all.

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